

Title: Tune...UM!**Brief Overview:**

This is a lesson in which the students collect real data related to sound. By using the TI-82 and CBL units both force and frequency will be graphically displayed. After collecting data, conclusions can be drawn.

Link to Standards:

- **Problem Solving** Students will investigate through experimentation with a real-world problem involving sound.
- **Communication** Students are encouraged to express mathematical ideas orally and in writing.
- **Reasoning** Students will make a conjecture about the problem solution and test its validity. They also are required to make and test conjectures in order to increase reasoning skills.
- **Connections** Students will recognize the connections between mathematics and other disciplines, specifically science and the arts.
- **Algebra** Students will apply knowledge and use tables, graphs, and equations as tools to interpret data.

Grade/Level:

Grades 9-12

Duration/Length:

This session is expected to take two 45 minute class periods. With the extensions it may take one extra class period. This lesson is particularly suited for class demonstration if equipment or time is limited.

Prerequisite Knowledge:

Students should be familiar with graphing and particularly the basics of waves. A brief preview is included for those who lack knowledge of terminology. Teachers should be familiar with both the calculator based laboratory (CBL) and the Texas Instruments Graphics Calculator (TI-82). If students have no experience with graphing calculators, the lesson may take longer than two class periods.

Objectives:

Students will be able to:

- work cooperatively in groups.
- observe what increase in tension does to the frequency of the sound wave.
- use the CBL and TI-82 to collect data.
- use the TI-82 Graph Link.
- interpret results and draw conclusions.
- express answers clearly in writing.

Materials/Resources/Printed Materials:

- CBL Unit (2 per group)
- TI-82 Graphing Calculator (2 per group)
- Extra calculator (any type) for computation as you proceed
- Unit to unit link cables (2)
- Vernier student force sensor (SFS-DIN) with CBL-DIN adapter (1)
- CBL Microphone (MCA-CBL) (1)
- Programs CBL, FORCECERT, and TUNED (Teacher Resource #2) both loaded into each calculator through the GRAPHLINK or by hand. Programs can be found in Exploring Physics and Math with the CBL System, 1994 and Real-World Math With the CBL System, 1994.
- Optional computer and printer with GRAPHLINK to print student graphs.
- Worksheets (Student Resources #1-3)
- Group equipment including wooden foundation, envelope of rubber bands, meter stick, and duct tape for holding meter stick in place.

Development/Procedures:

- Examine the rubber bands that have been given for physical characteristics and conjecture about the relationship between tension (force) and frequency.
- Divide students into groups of four.
- Assign the following roles within the group: Manipulate rubber bands while using the force probe and hold the microphone, operate the CBL and TI-82 linked to the force probe, operate the CBL and TI-82 linked to the microphone, and record and calculate data.
- Gather equipment and set it up following the technology procedure sheet.
- Execute the CBL/FORCECERT program to obtain a graph of force vs. time
- Execute the TUNED program to obtain a graph of sound vs time.
- Record data in charts provided and graph results using the TI-82
- Evaluate graphs using narrative and print them out using GRAPHLINK if available.
- Present results to the class via overhead transparency and group discussion.

Evaluation and Conclusion:

Students will be evaluated as they proceed with the experiment and participate in the class discussion. Each group should turn in their data collection sheet to be graded. A hands-on quiz can be devised for further evaluation.

Extension/Follow Up:

- An additional resource is Math and Music.- Harmonious Connections, Garland, T.H. and Kahn, C.V., Dale Seymour Publications, 1995. An essay or oral report could be assigned as a regular evaluation or an extra credit opportunity. You will be surprised to find fractals on pages 132-133.

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Tune ... UM!
Technology Set Up Procedure
Student Resource #1

Materials:

- CBL, two per group
- TI-82 Graphics Calculator, two per group
- Additional calculator, any type
- Unit to unit link cables, two per group
- Vernier student force sensor (SFS-DIN) with CBL-DIN adapter
- CBL- Microphone
- Student Resource Sheets #2 & #3, one per student
- For each group: wooden foundation, two rubber bands, meter stick, duct tape

Procedure:

The TI-82 should have programs already loaded on it by the teacher.

Force Probe:

- Link the TI-82 to the CBL using the unit to unit link cables and the ports on the bottom edge of each.
- Link the force probe, with CBL-DIN adapter to the CBL. The CH1 port is located on the top edge of the CBL.
- Make sure cables are firmly pressed into the ports.
- Turn on the TI-82.
- Press {prgm}; use {6} to go to <CBL>; {enter}; {enter}
- Use {6} to select <FORCE>; {enter}
- Use {6} to select <FORCE(RLTIME)>; {enter}
- Use {6} to select <AUTO>; {enter}
- Turn on the CBL
- Remove all forces from the probe, and press {enter} to zero it.

Microphone:

- Press {prgm}; use direction arrows to locate the TUNED program; {enter}
- Follow instructions on the screen.

You are now ready to continue with the Experiment Procedure Sheet.

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Experiment Procedure Sheet

Student Resource #2

The Problem: What is the relationship between frequency and tension (force)?

Which rubber band will have the highest frequency? Will stretching them change the frequency? Think of musical instruments you are familiar with! What do you expect to find? “Stretch” your minds and get ready to “pluck” some information!

☐ Place wooden foundation next to a meter stick, making sure that “0 cm” is aligned with the end of the foundation with the hook.

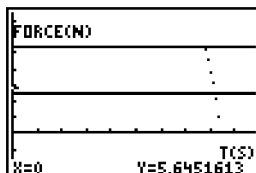
☐ Use duct tape to insure that foundation and meter stick remain aligned and stationary.

☐ Attach rubber band to hook on foundation.

☐ Insure force probe is “zeroed”

☐ Attach rubber band to force probe and pull to first desired distance as given on your attached chart. Collect data on the force needed to pull this rubber and by holding the probe as indicated in the diagram.

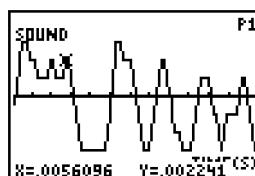
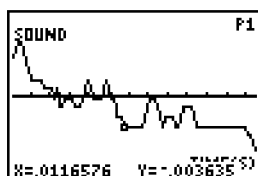
☐ A graph of the data collected will be plotted on the TI-82 display.



Press {2nd } <DRAW> {3} to display a horizontal line on the screen. Use the arrow keys to move up or down until the horizontal line aligns most appropriately with the data. The displayed y-value represents the tension (force). Record the y-value in the chart. Round to two decimal places.

☐ While the rubber band is extended, place microphone near hook under one of the rubber band strands. Using an upward motion, “pluck” the strand above the microphone.

☐ The following is an example of what will be seen on the TI-82 screen.



Locate two corresponding positions on the wave and determine values of x_1 and x_2 by using {trace} and direction arrows on the TI-82. Record on data charts.

▣ The same procedure will be used at each designated distance with each rubber band.

The student operating the force probe will need to reset the TI-82 by pressing {clear}, {clear}, {enter}, {4}, {2}, {1}. Remember to use {2nd}{draw}{3} and the arrow keys to get a horizontal line that matches the graph.

The student operating the microphone will need to reset the TI-82 by pressing {2nd}, {quit}, {enter}, {enter}, {1}, {2}. You are now ready to repeat procedure.

▣ After all data is collected, complete computations and answer questions as directed on the Data Collection Sheet.

Data Collection Sheet**Student Resource #3****Name of Lab Partners:** _____**RUBBER BAND #1**

Distance	Force	X₁	X₂	Frequency
15 cm				
20 cm				
25 cm				
30 cm				
35 cm				

RUBBER BAND #2

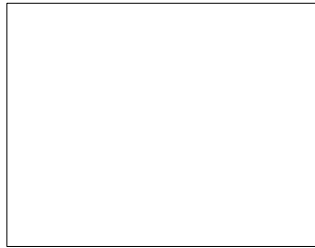
Distance	Force	X₁	X₂	Frequency
15 cm				
20 cm				
25 cm				
30 cm				
35 cm				

*****Frequency can be computed using the formula $1/(x_2 - x_1)$

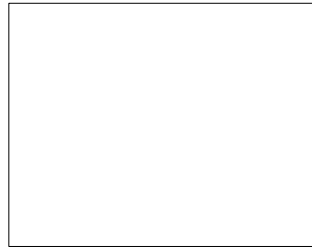
Conclusions and Observations:

1. Describe the visual appearance of your two rubber bands.
2. Identify what quantities are represented on both the x and y axes for the force graph.
3. Identify what quantities are represented on both the x and y axes for the sound graph.

4. After observing the data in your charts, what do you feel is the relationship between frequency and tension (force)?
5. In the window provided sketch what the sound waves would look like for both high and low frequency sounds.



HIGH FREQUENCY



LOW FREQUENCY

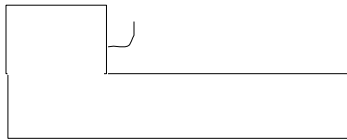
6. Explain why the force graph on your TI-82 was always a horizontal line? What kind of function is this?
7. Are force and frequency related *directly* or *inversely*?
8. If you are a guitarist, why do you re-position your fingers along the strings?

What variable are you changing and how?

9. Name other musical instruments that use this same concept....as many as you can!
10. Does this concept relate to drums? If so, how?

Teacher Resource #1

Materials: The required wooden foundation should be constructed prior to experiment. This would be a good opportunity to interact with the technology instructor at your school. A simple 2 x 4 section can be cut into an L-shape, attaching a hook to the shorter vertical section. This should be stable enough to withstand a fairly substantial pulling force that will be applied to a rubber band placed on the hook. A simple diagram appears below.



In choosing the two rubber bands to be given the students, make sure that one is thick and the other thin. In addition, each should be able to stretch easily to the designated distances (15-35 cm).

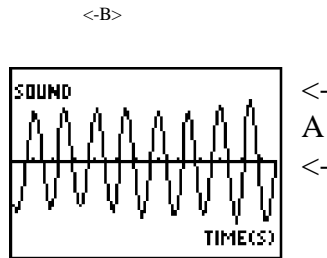
Programs:

The necessary programs are not included in this unit, but the sources are Exploring Physics and Math with the CBL System, Texas Instruments, 1994 and Real-World Math with the CBL System, Texas Instruments, 1994. A computer disk is provided with each; contents of the disks can be loaded onto your TI-82 using a GRAPHLINK.

Teacher Resource #2

To provide the teacher and student with background on sound, the following information may be helpful:

When a tuning fork is struck, a very clear tone is produced and a definite wave pattern can be observed. Its appearance allows us to describe some basics for **all** waves.



The section of the wave **A** indicates amplitude or “height” of the wave. Physically a wave of greater amplitude has more energy. In this experiment the sound would be louder. The section of the wave **B** indicates wavelength...a measure from one point on a wave to the same point on the next wave. It is easier to observe two crests or “peaks”.

The period of a wave is the time for one complete wave. The frequency is the reciprocal of period. In the case of a sound wave, the frequency determines pitch.

When the “plucking” of the rubber band occurs, its vibration disturbs the air and produces a sound wave. Your TI-82 calculator gives a graphical representation. Even though a “perfect” wave won’t result, you should be able to get several consecutive waves, especially near the beginning of the graph. Holding the microphone up near the rubber band will help. Repeat as necessary to get good results. We would expect that the thicker rubber bands have lower pitch and the increased tension (force) would result in higher pitch.